Tribological ~~Behaviour~~ Study of Bioinert Zirconia-- TtToughened Alumina ~~Bio-inert Biomaterial~~ Used in Total Hip Joint Implants

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Abstract

Zircon~~ia~~oughened aAlumina (ZTA) is an advanced ceramic bio-ine~~rt~~material comprising ~~of~~ 80% aAlumina and 20% yYttria- ~~stabilised~~stabilized ~~Zirconia~~zirconia. ~~These~~ It is used in a number ofseveral ~~bio-inert biomaterial is used in t~~~~ld of~~ medical applications, including ~~specifically in~~ total hip joint implants, ~~due~~ owing to its unique characteristics ~~of~~ such as ~~minimum~~ its low interaction with the surrounding tissue and good biocompatibility. This paper presents the ~~Triboligical~~tribological (~~behaviour or~~or ~~Wear~~ wear) ~~behaviour~~behavior of ZTA pins and ~~ZTA~~ p~~P~~lates when subjected to- wear tests. A Ducom Linear Reciprocating Tribometer was used for ~~testing~~ evaluating the ~~the~~ wear ~~in~~ characteristics of the ZTA p~~P~~in ~~and ZTA~~and p~~P~~late specimens. The ~~test results confirmed that the~~ average wear rate of the ~~ZTA pin and ZTA plate~~ specimens was ~~minimum as~~ low at 6.2498 ~~x~~X × 10^{-9} g/(N·m). Their coefficient of friction ~~of ZTA pin on ZTA plate~~ was ~~found to be~~ 0.333 for a~~,~~ frictional force ~~was found to be~~of 6.666 N and operating temperature ~~was~~ of 37 ± 0.2~~o~~ °C. These ~~above parameters were within the~~values are within the admissible limits as per the ASTM standards ~~used~~ for implant materials. Hence, ~~Zirconia toughened Alumina Bio-inert material is~~ZTA is a ~~agood candidate~~suitable ~~implant~~ biomaterial for t~~T~~otal hip joint ~~replacement~~ implants and other similar medical applica

Keywords: Zirconia, Alumina, Wear resistance, Composites, Biomedical applications

1. Introduction

Zirconia- ~~T~~toughened ~~Alumina~~ alumina (ZTA) is an advanced ceramic bio-inert biomaterial comprising ~~of~~ alumina and zirconia. It ~~ZTA~~ consists of 80% alumina, which is the primary phase, and 20% ~~of Y~~yttria- ~~S~~stabilized ~~Zirconia~~ zirconia, which is the secondary phase. This composite ceramic material combines the advantageous properties of both monolithic alumina and zirconia. ~~ZTA~~ As a result, it exhibits high strength and toughness compared with~~o~~ conventional alumina and zirconia. In addition, ZTA composites ~~have~~ show better mechanical properties compared ~~to~~ with ~~that of~~ monolithic alumina or stabilized z~~Z~~irconia alone [1]. The~~se properties are achieved by~~is can is becan be attributed to ~~using~~ several mechanisms such as ~~blocking~~ blocked crack growth, ~~by controlling~~ grain shape control, ~~controlling the~~control of the phase transformation ~~in~~ of the zirconia particles, and the ~~strengthening~~ strengthening of the alumina phase ~~through~~ by optimizing its ~~control of~~ grain size and introducing various additions.

~~Though A~~While alumina ~~has~~ exhibits high hardness and good wear resistance, its ~~properties~~ high~~but~~ brittleness ~~nature of alumina leads~~ results in ~~to~~ high ~~risk of~~ fracture risk, leading to~~.~~ ~~This property of alumina leads to certain~~ design restrictions. The ~~Zirconia has only half the~~ hardness of zirconia is half of that of alumina; however, its ~~but~~ fracture resistance is ~~improved~~ greater ~~due~~ owing to ~~to~~ transformation toughening. ~~The~~ Hence, its overall toughness and bending strength

Please check the changes I have made and use the revised version of the title for future references to this work. The revised title better reflects the
Editor
07/20/2026 12:41

"Comprising of" is redundant; "comprise" already means "made up of." Use "comprises" alone, or "consists of."
Editor
07/20/2026 11:37

Please clarify whether this is by weight or volume.
Editor
07/20/2026 11:46

"Due to" traditionally functions as an adjectival expression meaning "caused by" rather than "because of." Rule of thumb: if "due to" can be replaced with "caused
Editor
07/20/2026 12:20

Please note that the keyword list omits "Zirconia-toughened Alumina" (ZTA), the paper's central subject. "Zirconia" and "Alumina" appear separately, but
Editor
07/20/2026 12:20

In this case too, please clarify whether this is by weight or volume.
Editor
07/20/2026 11:48

Use it when you're examining differences between two things of the same class, which is almost always what quantitative comparison involves: "Group A
Editor
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are comparatively higher than those of ~~Alumina~~alumina. However~~In addition, But~~ zirconia ~~in a~~exhibits a metastable form phase transition, which ~~n occurs and~~ affects its overall stability [2]. The poor thermal conductivity of z~~Z~~irconia also ~~increases this~~aids~~contributes to this~~ phenomenon. Therefore, the ideal ceramic ~~is a~~would be a ~~material that~~ combine~~s~~ the best properties of both ~~Zirconia~~ zirconia and ~~Alumina~~ alumina:; one such material is~~which is popularly known as~~ z~~Z~~irconia- ~~T~~toughened ~~Alumina~~alumina.

A b~~B~~iomaterial is a natural or synthetic material used for medical application~~s~~ as~~because it .~~ is ~~Biomaterials are the materials that are~~ compatible with ~~the~~ living tissues. The important factors ~~that are~~ considered for a biomaterial are its physical properties ~~of the materials~~, corrosion ~~nature~~ characteristics in the tissue environment, and its surface configuration ~~of material~~. Based on the biological interaction~~s~~ ~~with~~ of biomaterials, they can be ~~material, biomaterials are~~ categorized into three types~~:. i.e.,~~ b~~B~~io-inert materials, b~~B~~io-active materials, and b~~B~~io-resorbable materials. Biomaterials may be m~~M~~etals and metallic alloys, ceramics, polymers, ~~and~~ or natural materials. The function of biomaterials ranges from being inert in the body to being "bioactive" and help~~ing~~ with regeneration [3].

Biomaterial~~s~~ are widely used for the restoration of damaged body parts through interaction~~s~~ with the living system~~s~~. Biomaterial devices used in orthopedics ~~is~~ are known as implants. Biomaterial-based~~s~~ ~~in form of~~ implants used in the human body include artificial heart valves~~;~~ blood vessel stents~~;~~ ~~and~~ shoulder, knee, and hip implant~~s;~~ elbow replacement implants~~;~~, and dental implant~~s~~.

A ~~Biomaterial~~ biomaterial should have the following desired properties [4]:

Mechanical properties: The material should have high strength so that ~~they~~ it can withstand ~~the~~ high load~~s~~. In addition, its ~~and~~ modulus of elasticity should be low. This ~~helps~~ would ~~to~~ help increase the service life of the implant~~s~~ and prevent the necessity of revision surgery ~~due~~ owing to the loosening of the implant.

Biocompatibility: The material should not cause any harm to the body and should be compatible with ~~the~~ living system~~s~~~~s~~.

Wear resistance: The material must possess high wear resistance and ~~have~~ a low coefficient of friction when sliding against body tissues. A low ~~Decrease in~~ wear resistance or ~~increase in the~~high coefficient of friction can lead to loosening of the implant.

Corrosion resistance: A biomaterial must possess high corrosion resistance. ~~The m~~Material~~s~~ with ~~less~~ low ~~resistance to~~ corrosion resistance can release~~s~~ metal ions ~~from the material to the~~within the body, resulting in ~~and it results in~~ toxic reactions ~~inbody~~.

Osteoconductivity: The biomaterial must allow bone growth on ~~their~~ its surface~~s~~.

Osseointegration: The propert~~y~~ies~~y~~ of the material should be such that ~~there is~~ are ~~both~~both functional and structural connection~~s~~ form between the surface of the load- carrying implant ~~material~~ and the living bone. ~~It is important that t~~The roughness, chemistry, and surface characteristics of the implant material play a major role in osseointegration.

Non-toxicity: The implant material must be nontoxic, that is, it must not result in toxic reactions ~~in~~ within the body~~,~~ and should not alter the DNA ~~of genome~~ (genotoxic) or ~~should not~~ cause damage to the individual cells (cytotoxic).

Fatigue life: The material must have high resistance to fatigue so that ~~the failure of~~ implant failure and its~~by~~ ~~and~~ fatigue fracture, which can ~~leading to stress shielding~~, can be prevented.

Bio-inertness: The material does must not not interact when introduced in within biological tissue. This helps in the formation of bone on the implant surface of material and aids the ion exchange of ions with the surrounding tissues.

Biotolerancent: The material is must not be rejected when implanted into living tissue.

Biomimetics: The material is must be designed to mimic specific biological processes, so that it and it helps in optimizinge the regenerative response in within the biological environment.

Total hip joint implant replacement is an unavoidable orthopedic application procedure for the patient suffering from arthritis patients and forseeking to improving improve their quality of life of patients [5]. Artificial joints which that replaces the damaged joint is are gaining popularity. The demand for Hip hip joint replacement in the field ofin orthopedic surgery is high, but it ismaking an still challenge for implant last remains a challengeto lastlong.

Standard total hip joint implants are made up of four components [6]. The]: S stem, it is the part inserted into the femur, or thighbone. The Cupcup, it is the part inserted into the pelvic bone. The Ballball , it is the part fitted onto the end of the stem. And the Linerliner, it is the part inserted into the cup;- it acts as the and becomes new cartilage.

Tribology is "the science and technology of interacting surfaces in relative motion and of related subjects and practices.". It generally includes technologically relevant phenomena such as friction, wear, and lubrication [7, 8]. Wear is the progressive loss of material from surfaces in contact, which occurs as a result ofbecause of friction. It is a slow and , continuous process of of removal of particle removals from one or more materials. Wear is not an intrinsic property of a material but rather it isa complex response of a material induced by the system characteristics, such as the load, speed, temperature, hardness, surface finish, and presence of foreign materials etc. [9]. The processes by which material experiences wear is are known as its wear mechanisms. This These mechanisms wear mechanism describes how the articulating surfaces behave for under different tribological conditions [10]. The different types of wear mechanisms experienced in a material may be abrasion, adhesion, third-body, fatigue, and corrosion [11].

The Parameters parameters affecting wear are as follows:include the C coefficient of friction, Frictional frictional force, and Operating operating tTemperature.

Please note that these two sentences contradict each other. The first says the material doesn't interact with tissue (bioinert), but the second says it promotes bone formation and ion exchange, which is exactly what a bioactive material does, like hydroxyapatite. A material can't be both. You have described ZTA as being bioinert throughout.
Editor
07/20/2026 12:06